# An Experimental Study on the Impact of Wire Mesh Fiber Addition on the Mechanical Properties of Preplaced Aggregate Concrete (PAC)

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**Abstract.** Concrete is the main material in construction, but it often experiences cavity problems in the structure that can reduce strength and durability. Preplaced Aggregate Concrete (PAC) is an alternative solution by placing coarse aggregate first, then filling mortar through the grout process. This study aims to determine the effect of the addition of wire mesh fibers on the mechanical properties of PAC, especially compressive strength and tensile strength. The research was conducted experimentally in the laboratory with five variations of wire mesh fibers: 0%, 0,25%, 0,5%, 0,75%, and 1% of the concrete volume. Grouting is carried out using the injection method, with a water-cement ratio of 0,45, a coarse aggregate of 38 mm, and a superplasticizer of 1%. Mechanical strength testing, including compressive strength, tensile strength, is carried out according to the ASTM standards. The results indicated that the addition of fibers lowered the compressive strength by 13,69% but increased the tensile strength by 64,06%. The highest compressive strength of 33,78 MPa is achieved by normal concrete and fiberless PAC, while the highest tensile strength of 4,95 MPa is achieved by PAC with 1% fiber wire mesh.

## Introduction

The selection of structural base materials is very important in development planning. Concrete frequently encounters issues in the field, such as void formation, despite its frequent use in construction. This void can weaken the structure's strength and stability, mainly because of retained concrete or a lack of compaction from either placing the concrete too deeply or in places where the bones are too close together.

The Preplaced Aggregate Concrete (PAC) approach is one of the creative ways to solve this issue. Using this procedure, coarse aggregate is first placed into the formwork, and then fine-graded mortar without a compaction process is used to fill in the spaces between the aggregates. The study's findings demonstrate that because of a more uniform distribution of stresses across the aggregates, PAC offers the advantages of high compressive strength and good density [1][2].

PAC still has drawbacks, though, much like regular concrete, particularly when it comes to mechanical qualities like low tensile strength and abrasive qualities. Numerous experiments have been conducted to enhance its performance by including fiber materials, including steel and polypropylene fiber, as well as industrial waste, like carpet fragments [3][4]. Nehdi et al. did research on the addition of fibers to PAC and demonstrated that the mechanical characteristics of PAC were considerably enhanced by the inclusion of steel fibers [5]. Portland Lime Cement (PLC) and precast aggregate steel fiber reinforced concrete (PASFRC) were combined in a novel way by Saleh et al. [6]. Long and short end steel fibers were added to PASFRC at concentrations of 1%, 2%, 3%, and 6%. The results demonstrated that the mechanical properties of PAC were enhanced by PLC and increasing fiber dosage. Compressive, tensile, and flexural strengths of the PASFRC combination containing 6% long steel fibers increased significantly after 90 days, reaching maximum values of 49,8 MPa, 7,7 MPa, and 10,9 MPa, respectively. Comparing these results to

PAC without fibers, we see increases of 188%, 166%, and 290%. Furthermore, Ngudiyono et al added wire fibers produced by cutting wire rope with a diameter of about 1 mm and a length of 60 mm to the PAC, the results of the study showed that the addition of wire fibers significantly increased the compressive strength, tensile strength, and breaking modulus of the PAC [7]. Though prior research has demonstrated the potential of various fiber types to improve the mechanical performance of PAC, few studies have not specifically investigated the effects of wire mesh fibers, particularly with varying volume percentages, on compressive strength, tensile strength, and modulus of elasticity. Moreover, previous research has rarely explored how variations in the volume fraction of wire mesh fibers influence not only the compressive and tensile strengths but also the modulus of elasticity of PAC. The lack of such studies has created a gap in understanding the overall mechanical behavior of PAC when reinforced with wire mesh fibers. Therefore, this study aims to address this research gap by experimentally investigating the effects of different wire mesh fiber contents (0%, 0.25%, 0.5%, 0.75%, and 1% by concrete volume) on the mechanical properties of PAC, including compressive strength, tensile strength, and modulus of elasticity.

This work aims to fill this research gap by experimentally investigating how the addition of wire mesh fiber affects the mechanical properties of Preplaced Aggregate Concrete (PAC), including compressive strength, tensile strength, and modulus of elasticity. Fiber volume variations of 0,25%, 0,5%, 0,75%, and 1% of the concrete volume were assessed.

## Method

**Experimental Program.** The materials used in this study include uniform 38 mm coarse aggregate from PT. Main Concrete Perkasa, and fine aggregate in the form of river sand with a maximum size of 2,36 mm. The water used comes from the Structure and Materials Laboratory, Faculty of Engineering, University of Mataram. The cement used is Portland cement type I of the Tiga Roda brand with a packaging of 50 kg per zak. The fiber used is a straight steel wire mesh, cut into segments measuring 60 mm in length and 0,7 mm in diameter, with an aspect ratio of 85. The superplasticizer used is Sika Viscocrete 3115N as much as 1% of the weight of cement.

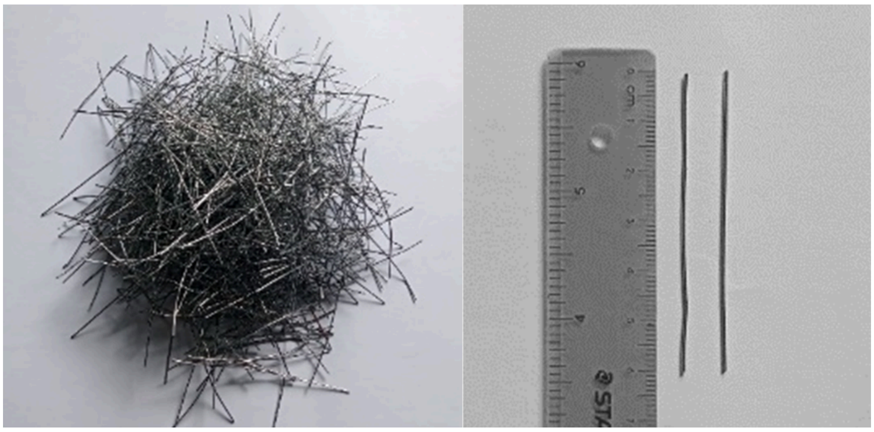

**Fig. 1.** Wire mesh fibers

The tests carried out included compressive and tensile strength tests. The test objects used were 36 PAC cylinders, with dimensions of Ø15 cm × 30 cm. These were created using a manual injection grouting method, which involved several stages. These stages are preparing the materials (cement, fine and coarse aggregates, wire mesh fibers, water, and superplasticizer). Also, mixing the mortar ingredients for around 4 minutes using a mixer. In addition, preparing and lubricating the formwork, positioning the injection pipes, and filling the coarse aggregate per ¼ of the formwork height, interspersed with the scattering of wire mesh fibers until full. Then, injecting the mortar into the base of the formwork until evenly distributed, leveling the surface with a straightedge, storing the molds in a humid place for 24 hours, removing the test objects from the molds, coding the samples, and curing by immersing them in water for 28 days.

**PAC Mix Design.** The planning of the Preplaced Aggregate Concrete (PAC) mixture aims to determine the optimal proportion of the constituent materials. The calculation of the mixture refers to the methods of Abdelgader , which are used to determine the material requirements per 1 m³ PAC [2]. The result of mix design as showed in **Table 1**.

**Table 1.** Mix Proportion per 1 m3

| Sample Code | Wire Mesh Fiber (%) | Cement (kg) | Fine Aggregate (kg) | Coarse Aggregate (kg) | Water (kg) | SP (kg) | Wire Mesh Fiber (kg) |
|---|---|---|---|---|---|---|---|
| PAC | 0% | 433,472 | 433,472 | 1321,267 | 195,062 | 4,335 | 0,000 |
| PAC-0,25 | 0,25% | 433,472 | 433,472 | 1321,267 | 195,062 | 4,335 | 18,405 |
| PAC-0,50 | 0,5% | 433,472 | 433,472 | 1321,267 | 195,062 | 4,335 | 36,810 |
| PAC-0,75 | 0,75% | 433,472 | 433,472 | 1321,267 | 195,062 | 4,335 | 55,215 |
| PAC-1,0 | 1,0% | 433,472 | 433,472 | 1321,267 | 195,062 | 4,335 | 73,620 |

**Properties Testing of Preplaced Aggregate Concrete (PAC)**

**Compressive Strength of PAC.** The compressive strength test was conducted according to ASTM C39, using cylindrical concrete specimens with dimensions of 150 mm in diameter and 300 mm in height [8]. The specimens were loaded axially in a compression testing machine until failure, and the maximum load was recorded to calculate the compressive strength. The compressive strength value (f'c) is obtained from the comparison between the maximum load P (N) and the cross-sectional area of latitude A (mm²).

$$f'c = \frac{P}{A} \tag{1}$$

**Tensile Strength.** Concrete is known as a brittle composite material with limited resistance to tensile stress. In some recent experimental studies, the splitting tensile test method has shown a higher level of reliability in reflecting the actual tensile strength value of concrete. This method refers to the standard procedure of ASTM C496 , using a cylindrical test specimen with a diameter of 150 mm and a height of 300 mm [9]. The test specimen is placed horizontally between the two loading plates on the compression testing machine, then subjected to a vertical axial load along the diameter axis until the test specimen splits due to the induced transverse tensile stress.

$$ft = \frac{P}{\pi\, x\, L\, x\, D} \tag{2}$$

**Modulus of Elasticity.** Concrete Modulus of elasticity (Ec) is a parameter that indicates the degree of rigidity of concrete, or the ability of concrete to undergo elastic deformation to a given stress. According to ASTM C496 , the modulus of elasticity is calculated using the following formula [10]:

$$Ec = \frac{(s2-s1)}{\varepsilon 2-0{,}00005} \tag{3}$$

Where Ec is the Modulus of Elasticity (MPa), $S_1$ is the stress at the moment of longitudinal strain 0.00005 (MPa), $S_2$ is the stress at the moment of 40% of the maximum load (MPa), $\varepsilon_1$ is the strain at $S_1$ and $\varepsilon_2$ is the strain at $S_2$.

## Results and Discussion

### Compressive Strength of Preplaced Aggregate Concrete (PAC)

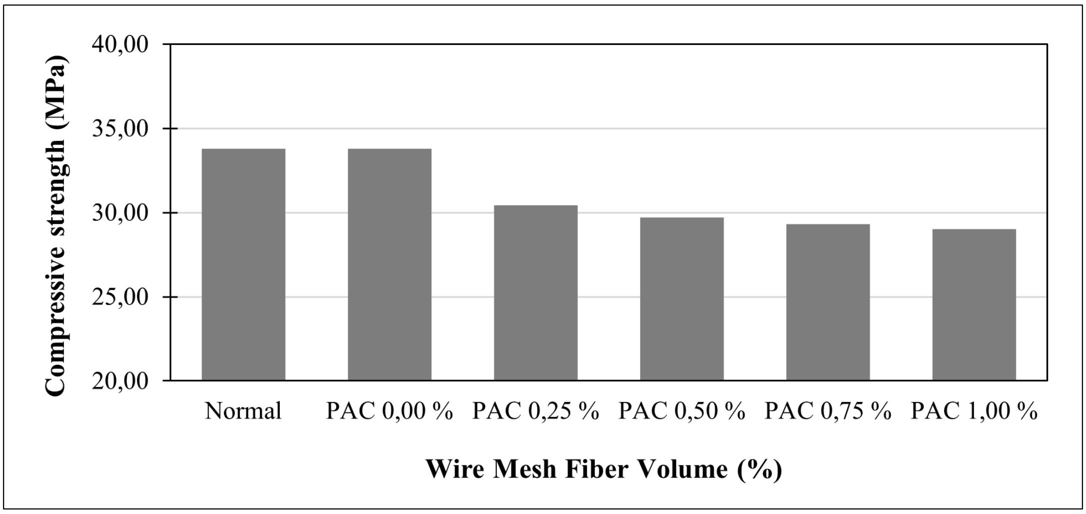


**Fig. 2.** Correlation diagram between wire mesh fiber percentage and compressive strength

Accoding to **Fig. 2**, the results showed that the addition of wire mesh fibers to the PAC mixture caused a decrease in the compressive strength value compared to normal concrete. At the percentage of 0% fiber, both normal and PAC concrete show a maximum compressive strength value of 33,78 MPa. However, as the percentage of wire mesh fiber increased, there was a gradual decrease in the compressive strength of the PAC, to 30,43 MPa (0.25%), 29,72 MPa (0.50%), 29,30 MPa (0,75%), respectively, and reached a minimum value of 29,02 MPa at the 1% fiber percentage.

### Splitting Tensile Strength of Preplaced Aggregate Concrete (PAC)

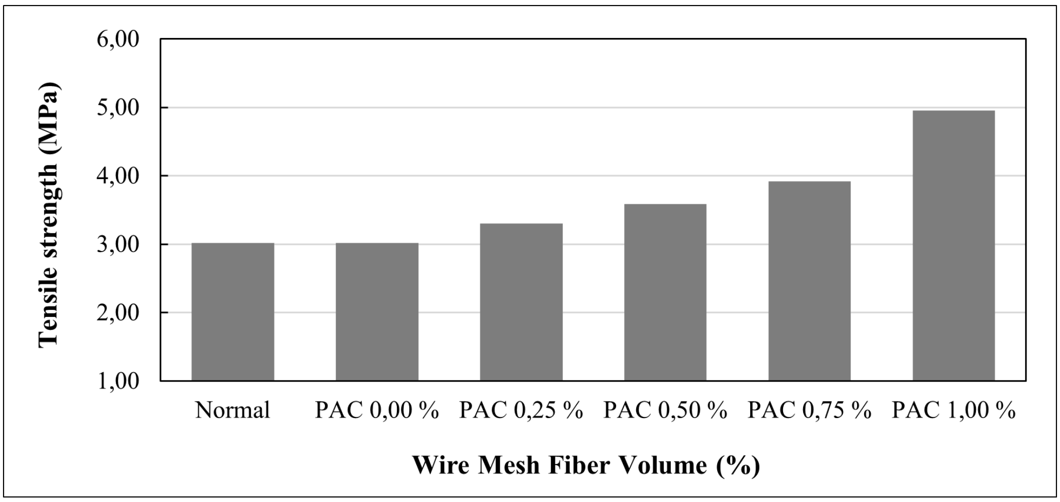


**Fig. 3.** Correlation diagram between the percentage of wire mesh fiber and tensile strength of concrete

Based in **Fig. 3**, the results of the study show that the addition of wire mesh fibers to PAC can significantly increase the tensile strength of concrete. The lowest tensile strength value, which is 3,02 MPa, is obtained in normal concrete and non-fiber PAC. As the percentage of wire mesh fibers increased, the tensile strength values increased successively to 3,30 MPa (0,25%), 3,59 MPa (0,5%), 3,92 MPa (0,75%), until reaching a maximum value of 4,95 MPa at PAC with 1% fiber.

## Elastic Modulus of Preplaced Aggregate Concrete (PAC)

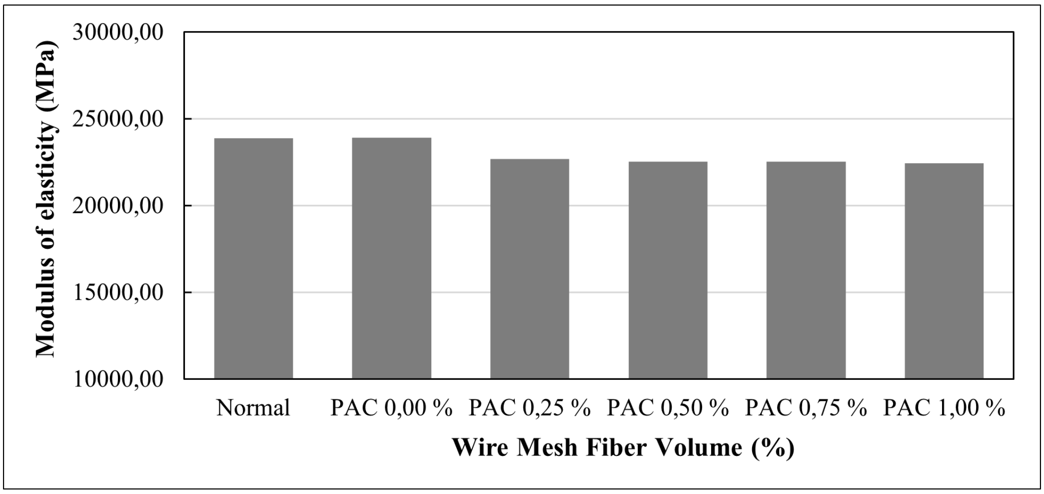


**Fig. 4.** Correlation diagram between the percentage of wire mesh fiber and modulus of elasticity

The test results show that the modulus of elasticity of concrete is directly proportional to the value of its compressive strength. Accoding to **Fig. 4**, the highest value was obtained in the non-fiber PAC (0%) of 23.896,32 MPa. The modulus of elasticity values in normal concrete, as well as PAC with the addition of wire mesh fibers of 0,25%, 0,5%, 0,75%, and 1% respectively is 23.883,05 MPa; 22.683,25 MPa; 22.541,06 MPa; 22.531,35 MPa; and 22.424,02 MPa. This decrease indicates that an increase in the percentage of wire mesh fibers in PAC mixtures tends to decrease the modulus of elasticity of concrete.

## Conclusion

According to the experimental results on the modulus of elasticity, splitting tensile strength, and compressive strength of Preplaced Aggregate Concrete (PAC) with different percentages of wire mesh fiber, adding wire mesh fibers reduced the concrete's compressive strength by 14,11% when compared to regular concrete, while increasing the splitting tensile strength by 64,06%, with the highest value of 4,95 MPa at 1% fiber content.

These results show that adding wire mesh fibers to PAC results in a trade-off between compressive and tensile behavior. The fiber-induced disruption of mortar flow during grouting, which may have resulted in micro-voids and compromised density, is responsible for the decrease in compressive strength. This is in line with findings by Nehdi et al., who also noted that decreased workability and fiber clustering caused strength reduction in PAC at high fiber dosages [5]. In a similar vein, Saleh et al. found that while high-volume steel fiber reinforcement (up to 6%) significantly enhanced tensile and flexural behavior, improper dispersion could have a negative impact on compressive strength [6]. In contrast, the increase in tensile strength is in line with prior studies e.g., Ngudiyono et al., where metallic fibers effectively bridged cracks and enhanced tensile load distribution [7]. The wire mesh fibers used in this study demonstrated similar crack-arresting behavior, leading to the observed strength gain.

With regard to the modulus of elasticity, the results also show a decline with increasing fiber content, from 23.896,32 MPa at 0% fiber to 22.424,02 MPa at 1% fiber. This trend supports the correlation between stiffness and compressive strength, as reported in Murali et al., where lower compressive resistance led to reduced modulus values [3]. Although the presence of fibers contributes to energy absorption and ductility, it does not compensate for the reduction in initial stiffness.

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